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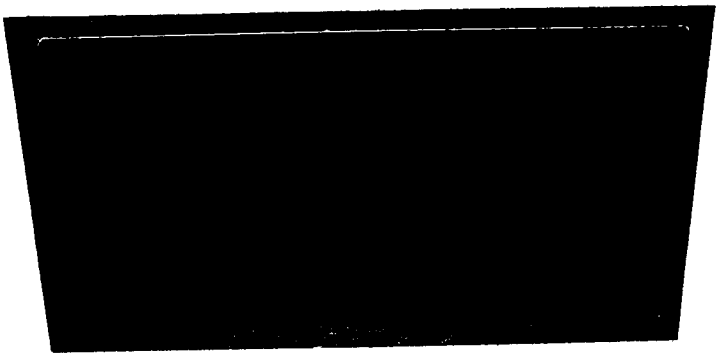

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PHASE I REPORT

LINEAR PHASOLVER SYSTEM

Prepared for

The U.S. Government

under

[redacted] STAT

October 1963

Prepared by

[redacted] STAT

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PHASE I REPORT

LINEAR PHASOLVER SYSTEM

1-1. SCOPE OF REPORT

This report describes the design concept, mechanization, and test results achieved during Phase I of the applied research program for developing and demonstrating the feasibility of a system for making measurements of linear movement with a resolution and accuracy of ± 1.0 micron or better.

1-2. SUMMARY OF REPORT

During the period covered by this report a simple, but effective, test fixture was designed and fabricated to hold the Phasolver transducer elements and provide for relative linear movement. An electronic system was developed and built to provide excitation signals for the transducer and to process and digitize the transducer outputs. A carry system was devised which solved the ambiguity of the fine count.

Two demonstrations were performed. The results were, as expected, completely successful. A resolution of approximately 0.2 microns was achieved despite the fact that resolution and accuracy were not prime objectives of this phase of the program. The system operated without ambiguity while measuring linear movement over a 6-pole-pair increment of the fine pattern (0.5 inch of travel).

In addition to the text of this report, the following drawings are submitted for clarification and study:

TITLE	DRAWING NO.
Test Fixture, Linear Phasolver	10002531
Phasolver Assy., Linear	10002532
Block Diagram, Linear Phasolver System	10002519

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TITLE	DRAWING NO.
Time Base	10002521
Ambiguity Counter and Decode Logic for 4-Level Delay	10002517
Counter Drive Logic	10002522

1-3. DESIGN CONCEPT

The design concept for this task is based on the Phasolver transducer principle, conceived and developed by STAT

1-4. PHASOLVER TRANSDUCER

The Phasolver transducer is a precision device which converts minute increments of mechanical motion into large increments of electrical phase-shift information. The phase-shift information is translated into elapsed-time format which, when incremented by clock pulses, provides an accurate readout.

1-5. PHYSICAL DESCRIPTION.- The linear Phasolver consists of two dimensionally stable plates which are fabricated of nonconductive material. Parallel bands of conductive material are applied to both plates and processed to provide the patterns which enable the Phasolver to perform its function. The patterns on the two plates are of different configurations and perform different functions. The patterns on one plate are utilized as the signal-drive element in the electrostatic coupling process and are designated as drive patterns. The patterns on the second plate are utilized as the coupling element in the electrostatic process and are designated as the coupler patterns.

a. DRIVER PATTERNS.- The driver plate utilizes two sets of drive patterns - fine and coarse. Both patterns are formed by a sinusoidal nonconductive area separating each band of conductive material to form two conjugate patterns.

(1) Fine Driver Pattern.- The fine driver pattern consists of two bands of sinusoidal conjugate patterns which are physically phase displaced by 90 degrees.

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Therefore, four patterns are provided to accommodate the required four quadrature drive signals. The pattern is extremely fine. For example, one cycle (pole-pair) of the demonstration element is 0.08 inch in length.

(2) Coarse Driver Pattern.- The coarse driver pattern differs only in the number of pole-pairs. This pattern is utilized for a coarse measurement of linear displacement to resolve ambiguity and establish a unique output. The linear phasolver system utilizes a ratio of one coarse-pattern pole-pair to 256 fine-pattern pole-pairs.

b. COUPLER PATTERNS.- The coupler patterns (coarse and fine) consist of alternate bars of conductive material and spaces of nonconductive material. The width of the bars and spaces are equal and are of the same dimension as one-half wavelength of the associated driver pattern.

1-6. FUNCTIONAL DESCRIPTION.- The four drive patterns are each excited by one of the four sinusoidal quadrature drive signals. The frequencies are the same but are displaced from each other by a 90-degree phase difference.

The driver and coupler plates are mounted so that the two patterns face each other, closely spaced. The relative amplitude of the drive signal which is coupled from each driver pattern is a function of the area of the driver pattern encompassed by the coupler-pattern bar. The output provided by the coupler pattern at any position is the vector sum of the coupled drive signals.

A minute change in the relative position of the driver with respect to the coupler varies the relative amplitude of the quadrature signals coupled from the driver to the coupler pattern. This results in a change in the vector summation and causes a change of phase in the constant-amplitude sinusoidal output signal. This phase shift increases continuously from 0 to 360 degrees as the moving element moves a distance equal to one sinusoidal driver pattern. Because of the symmetry in arrangement of the pattern-pairs and coupler bars of the fine patterns, an average output of all pattern-pairs is obtained. This averaging effect results in minimizing errors introduced because of nonlinear pattern-pair spacing.

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1-7. ELECTRONICS

The analog electronics required for the linear phasolver system include circuits to generate sinusoidal drive signals for the transducer and circuits to convert the phase-shift transducer output signal into elapsed-time format.

Electronics required to digitize the elapsed-time information includes clock-pulse generators and output counters.

1-8. MECHANIZATION

Existing linear Phasolver elements were utilized in the demonstration model. The test fixture to hold the Phasolver elements and guide the relative motion is shown in drawing 1000-2531.

The fine driver pattern contained 12.5 pole-pairs per inch, each pole-pair being 0.08 inch in length. Only a small segment of the coarse driver pattern was utilized in the test.

The complete system used for the Phase I demonstration is illustrated in the block diagram (drawing 1000 2519). The bench assembly of the system is shown in drawing 1000-2532.

1-9. TIME BASE ELECTRONICS

The time base for the system was established by a 400-kc crystal oscillator and a count-down timing chain. The output of the 400-kc oscillator, in addition to driving the timing chain, provided the 400-kc clock pulses for the coarse channel count. Timing-chain outputs were utilized to derive the start pulses and drive signals for the fine and coarse channels.

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1-10. FINE CHANNEL ELECTRONICS

The 6.25-kc square-wave output from the timing chain is filtered to provide the basic 6.25-kc sinusoidal drive signal. Operational amplifiers are used to provide the phase displacements which create the four quadrature drive signals.

The output of the fine coupler pattern of the Phasolver transducer is displaced in time from the fine start pulse by an increment which is a function of the linear movement to be measured.

The start and stop pulses are utilized to start and stop a time-interval counter which incorporates a 100-megacycle clock-pulse generator.

1-11. COARSE CHANNEL ELECTRONICS

The 1.5625-kc square wave output from the timing chain is filtered to provide the sinusoidal coarse drive signal. Coarse channel signal processing is the same as that for the fine channel, up to the point at which the coarse-channel stop pulses have been formed.

1-12. CARRY SYSTEM

The coarse-channel stop pulses are purposely delayed, prior to their application to the coarse-channel output counter. A zero-setting delay circuit permits the necessary manual compensating adjustment of the coarse stop pulse. A four-level delay, controlled by logic derived from the fine-channel count, causes a count to be carried to the coarse channel counter at the time of transition from one fine-channel pole-pair to another.

The coarse stop pulse is repositioned three times during the increment of linear movement which encompasses one fine pole-pair. This maintains the coarse stop pulse midway between two coarse clock-pulse periods. The fourth step in the four-level-delay carry system occurs at the time that the fine count returns to zero. At

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this time the coarse stop pulse is caused to advance one coarse clock-pulse period, thereby generating a carry which is counted by the coarse channel output counter.

1-13. FEASIBILITY DEMONSTRATION

After rigid tests, demonstrations of the system were performed using the setup shown in drawing 1000-2532. The first demonstration was conducted for the consultant to the customer, one week prior to the scheduled date for the completion of this phase of the program. At the scheduled time the final demonstration was conducted for representatives of the customer.

The demonstration of feasibility was made by moving the coupler pattern over a linear dimension of 0.5 inch, transversing six fine pattern pole-pairs of the driver element. A monotonically increasing count was registered on the fine channel output counter and the coarse channel counter registered the carries. The resolution of the count in the fine channel was 0.2 micron and the carry-system registry in the coarse channel counter successfully resolved the ambiguity.

1-14. PROBLEM AREAS

A major problem in the design and fabrication of a demonstration model was the critical nature of the gap between the plates and the relative alignment of the driver and coupler patterns. The fixture required to obtain an accuracy of ± 1 micron must be significantly more precise than the one used for Phase I.

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